Abdominal Electromyography During Micturition

ERNEST BORS, M.D., and KENNETH A. BLINN, M.D., *Long Beach*

■ *Electromyographic tracings during micturition were obtained from the abdominal muscles of volunteer men by means of silver cup electrodes.*

Electromyographic tracings of cough, strain and volitional and sphincter contraction were made before and after voiding on desire and on volition.

While the EMG activity of cough and strain remain unchanged, that of volitional and sphincter contraction underwent various changes following both types of voiding.

Before or at the onset of micturition on desire *the EMG remained unchanged in ten of 14 subjects, but with cessation of micturition it remained unchanged in only seven subjects while it increased in the remaining seven.*

Before or at the onset of micturition on volition *the EMG remained unchanged in seven of nine subjects, and with cessation of micturition it remained unchanged in eight of the nine subjects.*

Interruption of micturition increased the EMG activity of six among seven subjects, but resumption of micturition did not alter the EMG in five of the seven subjects.

Great variations existed in regard to urinary volume and flow rate.

It is proposed that there is an association of movements between the abdominal and pelvic floor muscles and that these movements are more conspicuous with cessation and interruption than with onset of physiological micturition.

THE ROLE of the striated musculature during micturition in general and that of the abdominal muscles in particular has been a much discussed and controversial subject, ever since opinions were expressed by LeGros-Clark in 1883[14] and Genouville in 1894.[8] Recordings of muscle activity were then not done; conclusions were drawn from introspection or other observations, but doubt existed whether or not the abdominal muscles partake in the act of voiding; LeGros-Clark[14] denied it flatly; Genouville[8] believed that these muscles come into play during micturition on volition or command but not on desire.*

Electromyographic surface recordings of the abdominal muscles of enuretic persons have been performed by Ditman and Blinn.[4] The abdominal muscles did not contract when the individual was

From the Spinal Cord Injury Service and the Electroencephalograph Unit of the Veterans Administration Hospital, Long Beach, California and the Department of Surgery, University of California, School of Medicine, Los Angeles.

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*The distinction between *volition* and *desire* as used here was subjective: *volition,* entirely at the wish of the subject without sense of urgency; *desire,* on physical reminder of necessity.

deeply asleep (as assessed by simultaneous electroencephalographic tracings) but did contract when the patient was in a state of wakefulness.

One of us[3] started to study the electromyographic activity of the abdominal muscles of neurologically and urologically intact persons by means of cup rather than needle electrodes, during micturition on desire and volition. The tracings were made with the subject in the supine position. Inasmuch as the physiologic posture of the adult male is upright during micturition, this position was chosen for the present study.

Material and Methods

A total of 17 adult male volunteers were subjected to a total of 29 observations. Twelve subjects were between 20 and 40 years of age; five were above 40. If micturition on desire was to be tested, the individual was instructed to hydrate himself well before the electromyographic recording; no hydration was advised when micturition on volition was tested. Before and after micturition, the effects of cough, of strain and of volitional contraction of the pelvic floor musculature on the electromyogram of the abdominal muscles were recorded. From the onset of the test the individual was so positioned as to be able to urinate freely into the vessel without supporting it or his penis, thus avoiding movement artifacts.

Electromyographic recordings were made on a Grass model IV-B electroencephalograph machine, using eight of the available 16 channels. Gains used were 1 centimeter per 100 microvolts for bipolar leads and 1 centimeter per 150 microvolts for "monopolar" leads. The paper speed was 3 centimeters per second in all recordings. Standard electroencephalogram silver cup electrodes and conducting salt paste were employed because of their inherent comfort and ease of application. The electrodes were held in place by a recently available perforated plastic adhesive tape (Bauer and Black) which allows good adhesion in the presence of salt paste or perspiration moisture. Four "active" electrodes were placed on the anterior abdominal wall, overlying the right and left, superior and inferior, segments of the abdominis rectus muscles. A relatively "indifferent" reference electrode for monopolar recording was placed over the right iliac crest or the anterior/superior iliac spine.

Four bipolar electromyograph leads were derived from the four active electrodes, and four "monopolar" leads were recorded simultaneously from these electrodes plotted against the iliac "indifferent" electrode. Electrocardiographic potentials intruded upon all recordings of these leads. No attempt was made to suppress them through electronic techniques, since they did not obscure the electromyographic potentials to a critical extent.

Instantaneous and continuous recording of the urinary output was first attempted by having the urinary stream intersect two wire grids, which were connected in a bridge circuit to measure the electrical resistance of the urine. This method had to be abandoned because of electrical interference in the electromyograph channels, which occurred whenever the stream was continuous enough to constitute an electrical connection between the subject's penis and the inputs of the electroencephalogram machine. All methods of grounding, shielding, voltage isolating and "floating the inputs" failed to resolve this problem. A metal can, used as a urinal in some of the early experiments, was noted to respond acoustically to the urinary stream. This response was used as a signal source, eliminating all electrical connection between the subject and the electroencephalogram machine. In lieu of a contact microphone, the can was fitted with a high-voltage-output Rochelle salt crystal phonograph cartridge. A copper wire soldered to the side of the can was inserted into the needle receptacle of the cartridge.

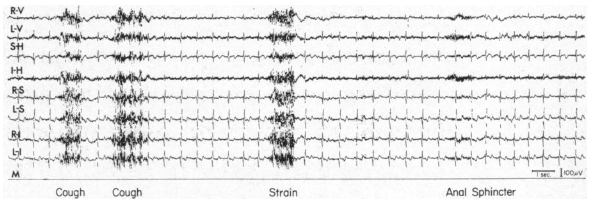

Figure 1.—The top eight channels of recording are abdominal electromyograms, four channels bipolar and four channels monopolar. Bipolar electrode pairs are designated as follows: RV = right vertical, LV = left vertical, SH = superior horizontal, and IH = inferior horizontal. The monopolar leads are designated according to quadrants: RS = right superior, LS = left superior, RI = right inferior, and LI = left inferior. The ninth channel displays signals from the urinary flow transducer, as described in the text.

The subject was a man 55 years of age. The tracings show high amplitude burst of abdominal muscle activity accompany coughing and straining. Voluntary contraction of the anal sphincter is accompanied by less intense but distinct bursts.

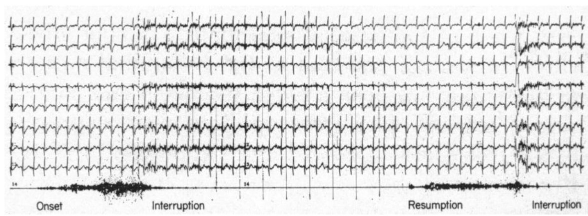

Figure 2.—The subject was a 23-year-old man. With the onset of the urinary stream (bottom channel) and during urination as represented by the thickened areas along the lower line, the existing EMG activity of the abdominal muscles diminishes, only to increase above the resting level upon interruption of micturition. These events are illustrated twice.

The wire leads from the cartridge were then taped to the side of the can to stabilize the cartridge mechanically and to impose a certain amount of mechanical damping. The signal output from the cartridge consisted of many high-frequency components which could not be recorded fully by the electroencephalogram oscillograph. In order to reduce this high-frequency information to an "energy envelope" which would accommodate the electroencephalogram machine's frequency capabilities, a signal-conditioning circuit was employed. This consists of a semiconductor diode rectifier and a pi type filter, shunted by a resistor of proper value for imposing a decay time-constant appropriate to rapid "on and off" events within the urinary stream. The voltage from this network is more than adequate for the electroencephalogram amplifier. Recorded on a ninth channel of the electroencephalogram machine, the signal appears as a "spiky" pattern, the amplitude and density of which vary directly with the flow rate and projectile velocity of the urinary stream. Individual drops or spurts of urine are clearly recorded.

This method allows an artifact-free recording of abdominal electromyographic activity, along with an exact measure of onset and duration of micturition and an approximate measure of "strength" of the urinary stream. The method also has an advantage of permitting the subject to direct the stream in a normal way, at a relatively unrestricted target.

Observations

Twenty-nine examinations were done in 17 subjects. Micturition on desire was observed in 14 subjects (19 examinations); micturition on volition or command was observed in nine subjects (10

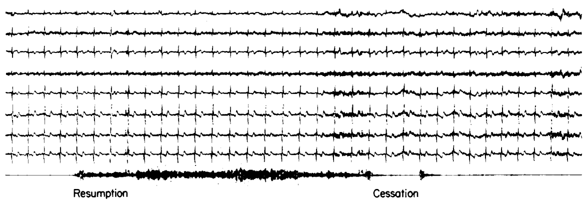

Figure 3.—The subject was a man 55 years of age. These tracings demonstrate that the EMG activity may not change on resumption of an interrupted micturition, but increases during the phase of cessation of micturition. The urinary flow recording (the thickened areas in the lower line) displays two spurts, each preceded by an EMG increase. Thereafter, a few drops of urine are recorded.

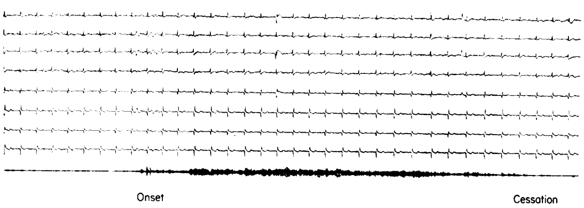

Figure 4.—The subject was a man 30 years of age. A "placid" micturition (duration shown by thickened area of lower line) is exemplified by absence of any EMG changes.

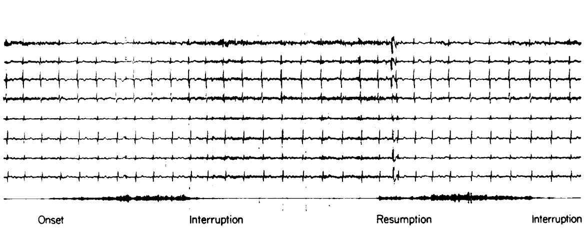

Figure 5.—The subject was a 31-year-old man. Onset and resumption of micturition (duration shown as thickened areas of lower line) are not accompanied by changes in EMG activity. However, pronounced increases coincide with and outlast interruptions of urinary jets.

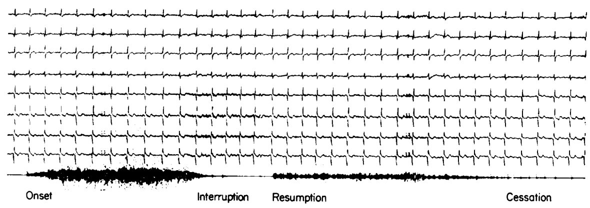

Figure 6.—The subject was a 30-year-old man. No EMG changes accompany onset, resumption and cessation of micturition; but a clear increase marks the interruption of the stream. The periods of micturition are shown by the thickened areas along the lower line.

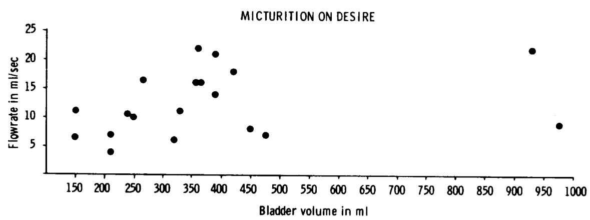

Figure 7.—Scattergram of micturition on desire.

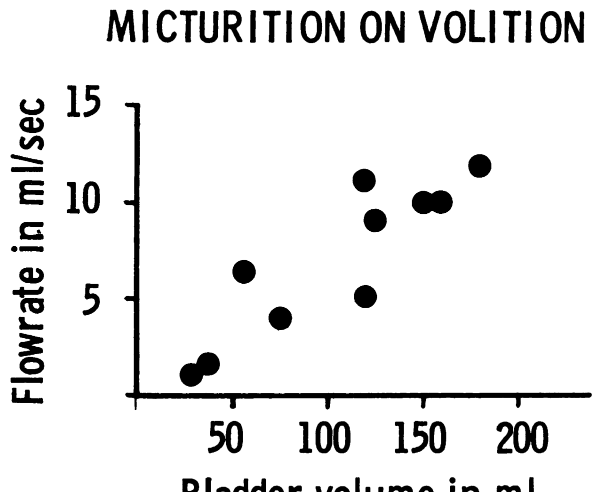

Figure 8.—Scattergram of micturition on volition.

examinations); and both forms of micturition were studied in five subjects.

The electromyogram (EMG), associated with cough, abdominal strain and volitional anal sphincter contraction, changed rarely when tracings before micturition were compared with those after micturition.

With micturition *on desire* the following was observed: The "cough" EMG before micturition was positive in 18 examinations (Figure 1) and was not tested in one. After micturition, it remained unchanged positive in 14 examinations and was not tested in five examinations.

The "strain" EMG before micturition was positive in 18 examinations and was not tested in one. After micturition, it remained unchanged positive in 16, increased in one and was not tested in two examinations.

The "anal sphincter" EMG before micturition was positive in 14 examinations, was equivocal in one, was zero in one and was not tested in three examinations. After micturition, it remained unchanged positive in seven examinations, was equivocal in two, remained zero in one, was not tested in one, increased in five and decreased in three examinations.

With micturition *on volition* the following was observed: The "cough" EMG before micturition was positive in ten examinations. After micturition, it remained unchanged positive in eight and was not tested in two examinations.

The "strain" EMG before micturition was positive in ten examinations. After micturition, it remained unchanged positive in eight, increased in one and decreased in one examination.

The "anal sphincter" electromyogram before examination was positive in six examinations, was equivocal in three and was absent in one examination. After micturition, it remained unchanged positive in four examinations, remained zero in one, increased in one and decreased in four examinations.

Onset and cessation of micturition *on desire* (14 subjects) altered the EMG as follows: Onset: EMG changes appeared in four subjects, no EMG changes in ten subjects. The EMG increased in two subjects, increased for eight seconds and decreased for three seconds before voiding in one, and decreased during voiding in one subject (Figure 2). Cessation: The EMG increased in seven subjects (Figure 3) and remained unchanged in seven.

Onset and cessation of micturition *on volition* (nine subjects) altered the EMG as follows: Onset: The EMG increased in two subjects and remained unchanged in seven subjects. Cessation: The EMG increased in one and remained unchanged in eight subjects (Figure 4).

Volitional interruption, resumption and ultimate cessation of micturition were examined in seven subjects; in four subjects micturition was studied on desire, and in three on volition. The EMG increased in three of the four subjects with interruption of micturition on desire (Figures 5 and 6) and in all three subjects with interruption of micturition on volition—that is, six of the seven subjects showed increased EMG changes with interruption of micturition. The EMG remained unchanged in three of the four subjects with resumption of micturition on desire, and in two of the three subjects with resumption of micturition on volition—that is, five of the seven subjects showed no EMG changes with resumption of micturition.

It should be noted that the same individual who showed an increased EMG with onset and resumption of micturition showed no increase with interruption and cessation of micturition. Two subjects showed an increased EMG with interruption but not with cessation, and one showed an increased EMG with interruption and cessation of micturition.

The volumes and flow rates varied greatly; the volume at micturition on desire ranged from a minimum of 150 ml to a maximum of 975 ml; the flow rate ranged from a minimum of 6 ml per second to a maximum of 22 ml per second. (Figure 7). The volume at micturition on volition ranged from a minimum of 30 ml to a maximum of 180 ml; the flow rate ranged from a minimum of 1.2 ml per second to a maximum of 12 ml per second (Figure 8). One subject had the same volume (150 ml) with both micturitional types: desire and volition. Of the seven subjects with 18 examinations only three showed a consistent trend of ratios of volume to rate of flow. Only three subjects reached a flow rate of 21 and 22 ml per second during micturition on desire; one of these had a volume of 930 ml at the other extreme, another individual with a volume of 975 ml had a flow rate of 9 ml per second.

Discussion

The aim of this study was to maintain, as much as possible, physiological conditions during the observations. We endeavored to examine events as they take place naturally rather than to investigate micturition under such pathological conditions as obtain from paralysis of parts or all of the striated musculature associated with this act. (Investigations of simulated conditions of that kind have been done by other observers by either pudendal nerve block[11] or by curarization.*) For this reason, we abstained from using needle electrodes[1] because they present a more disturbing factor than cup

*References Nos. 12, 13, 5, 17, 15.

electrodes; for the same reason we examined the subjects in the upright rather than in the supine position, as was done in a scout study.[3] Even with all precautions, the process of micturition cannot be called completely physiologic because of the physical and psychological influences unavoidable in the experiment. Thus, two persons whose electromyographic tracings were readily obtained had to be eliminated because they were unable to urinate while being watched by the necessary observer in the control room.

Tracing the EMG effect with cough, strain and anal sphincter contraction (Figure 1) was originally intended to establish a base line reading with which EMG changes could be compared as they might occur at onset, during and with cessation of micturition. While it was not surprising to obtain a good EMG tracing with cough and strain, it was astounding that this occurred also from anal sphincter contraction. This points to an associated facilitation of pelvic floor and abdominal muscle movements. Undoubtedly this varies between persons; it was present in 11 of the 14 subjects, was consistently absent in one and equivocal in two subjects. The EMG tracings with cough and strain after micturition hardly changed from those before micturition, whether it was micturition of desire or of volition. Far more changes were observed in the EMG associated with contraction of the anal sphincter, which was used as representative of the pelvic floor. However, these increases or decreases, following micturition on desire or volition, varied not only between persons but also from one time to the next in the same person, as observed on repeated examination. This tends to confirm the assumption of Petersén and coworkers[15] who, having demonstrated inter-individual EMG variations of these muscles with micturition, suspected intra-individual variation of function of the pelvic floor musculature.

A majority of persons showed no EMG changes at the onset of micturition either on desire or volition. Here, too, intra-individual variations were conspicuous on repeated examinations of two subjects, who showed an inconsistent increase of the EMG activity at the onset of micturition on desire. A decrease of the EMG activity (Figure 2) was found only in one; an increase followed by a decrease of the EMG activity was seen in another individual. This points, perhaps, to an associated inhibition of pelvic floor and abdominal muscle movements. Thus, it would appear that the phasic contraction of the abdominal muscles plays a minor role in physiologic micturition on desire; this was also observed in the previously reported scout study[3] of subjects in supine positions. Abdominal muscle activity was then not studied sufficiently with micturition on volition. It now has been shown that such phasic contraction of the abdominal muscles is rare also when the onset of micturition is volitional.

Cessation of micturition on desire was accompanied by an increased EMG activity in one-half of the 14 subjects. At times this could be correlated with the expulsion of the last urinary spurts (Figure 3) but in other instances it could not be correlated. This phenomenon of correlation was also observed in two of eight subjects of the scout study.[3] The fact that it occurred in only one of the nine subjects with cessation of micturition on volition suggests perhaps that detrusor activity and abdominal muscle activity are differently associated during micturition on desire and micturition on volition. The former is set off as a reflex response to the stimulus of detrusor stretch. (The bladder volume ranged from 210 to 930 ml.) The events taking place at expulsion of the last portion of urine perhaps can be compared with those during the last phase of labor, when reflex contractions of the abdominal muscles aid the contraction of the hollow viscus. Micturition on volition is induced by cerebral "recall" which triggers the associated movements of detrusor contraction and pelvic floor relaxation.[9] Thus, no stretch stimulus ever reaches the level of awareness, because it does not exist. An excellent sample of "placid" micturition on volition without any EMG changes at the onset or cessation is shown in Figure 4.

In pursuing the study of association between the pelvic floor and abdominal musculature, seven subjects were examined with interruption and resumption of micturition on desire (four subjects) and volition (three subjects). In concurrence with the abdominal EMG findings, accompanying volitional anal sphincter contraction, six of the seven subjects showed also an increased EMG activity on interruption of micturition (three on desire, and all on volition). One of the four subjects had also an increased EMG activity when micturition on desire ceased (Figure 5); the recording of the urinary stream suggests that this event coincided with the contraction of the ischiocavernosus and bulbocavernosus muscles. Two persons did not show this effect, although both had an increased EMG activity with interruption of micturition on desire (Figure 6). In one subject in whom there was increased EMG activity at the onset of micturition on desire, there was no such increase on interruption of micturition. In one person in whom onset of micturition on volition was not accompanied by increased EMG activity, resumption of micturition was.

In summing up all these findings it would then appear that phasic contractions of the pelvic floor cast their shadow upon the abdominal muscles, while relaxation of the pelvic floor is far less frequently associated with phasic changes of the abdominal musculature. The logical conclusion—not actually tested here—would be that the intra-abdominal pressure should increase when both the abdominal muscles and the pelvic floor muscles undergo phasic contractions. The various forms of micturition, "squirting" or "intermittent," as described by Petersén and coworkers,[15] proceed in spite of demonstrable EMG activity of the pelvic floor muscles; it would have been interesting if EMG of the abdominal musculature had been recorded. A study combining EMG activity of the abdominal and pelvic floor muscles would be of greatest interest, provided cup electrodes were used instead of needle electrodes.[1]

The flow rate presented here, cannot be compared with the curves obtained on uroflowmetry, but represents only the rate of the total urine volume over the total time. As in the preceding scout study, the majority of flow values were below the proposed average of 20 ml per second[10] or 23 per second[16]; they were also below the averages reported by Drake.[6] They compare, perhaps, with the averages observed in normal women.[2] That great variations of the maximum voiding rate exist[2] could be confirmed in this study. On repeated examination of the same seven persons, three showed consistency between volume and flow rate—that is, an increased flow rate with a greater volume[7]—but four did not show such consistency.

Micturition on desire was differentiated from that on volition by the subjective sensation of the patient rather than by the volume, although the volume on volition stayed below 200 ml. Conversely, volumes of less than 200 ml elicited the sensation of desire to micturate in two of the persons in the study. How much psychic stimuli play a role is illustrated by the subject who on one occasion urinated on volition, on other occasion on desire —the volume of urine being the same both times.

As suggested in the scout study of males in the supine position, it seems reasonable to assume that the flow rate in the upright position is also subject to psychic factors. It would be hard to assess in which instances embarrassment has been overcome by "training." This embarrassment was also conspicuous in the relatively long time interval between the command to void and the recorded urinary flow, irrespective of the type of micturition, desire or volition. In summary, this study confirms the findings of other investigators,[16] namely that variations of the flow rate exist on repeated determinations.

Veterans Administration Hospital, 5901 East Seventh Street, Long Beach, California 90804 (Bors).

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